

The Brazilian Cretaceous

By

IGNACIO MACHADO BRITO & DIÓGENES de ALMEIDA CAMPOS^{*)}

With 1 text figure and 1 plate

ABSTRACT

The Cretaceous is one of the best known systems in Brazil, being very well represented in the basins of the Northeast, on the continental shelf and covering the large palaeozoic basins.

The system is presented in its most complete form on the coastal and interior basins of the Northeast, since the Jura-Cretaceous transition until the Maastrichtian-Tertiary.

It can be divided into four phases: continental or prerift, lacustrine or rift, transitional or saline, and marine.

Owing to the impossibility of correlating the three first phases with the international stratigraphic column, we here propose to them local stages which could also be identified on the African Atlantic coastal basins: Donjoanian, Bahian and Alagoan.

The marine phase can be recognized since the Upper Aptian and it is almost perfectly correlated to the standard geological column.

KURZFASSUNG

Die Kreide ist eines der bestuntersuchten Systeme in Brasilien; sie ist verbreitet in den Becken Nordost-Brasiliens und auf dem Schelf. Am vollständigsten ist sie vertreten von der Jura/Kreide-Grenze bis zur Maastricht/Tertiär-Grenze in den Küstenbecken und den im Landesinnern gelegenen Becken die Nordost-Brasilien repräsentieren. Man kann 4 Phasen unterscheiden: „Kontinental oder prärfiting, Binnensee oder

„rifting“, Übergangsphase oder brackisch-salinar und vollmarine Phase. Da die ersten 3 Phasen nicht international zu korrelieren sind, werden 3 lokale Einheiten benannt und definiert, die sich auch in den westafrikanischen atlantischen Küstenbecken erkennen lassen: Donjoanian, Bahian und Alagoan. Die vollmarine Phase setzt mit dem Ober-Apt ein und ist bereits sehr gut mit dem internationalen Standard korreliert.

INTRODUCTION

The first geologists to recognize Cretaceous terrains in Brazil faced initially a problem of classification. Subsequently, a comparison was made to European stages, or even to North American ones, taking into consideration the fossil content was made easy by fossil comparisons, which later turned out to be correct within some limits, however, when continental units with endemic fossils were considered, the situation became enormously complicated. At first these designations were tentatively identified by European standards applied to local continental names such as Purbeckian and Wealden. Later, local names were used. So appeared the famous “series” which at first were applied exclusively with a chronostratigraphic connotation. Soon, however, that connotation was lost, and the “series” were then utilized as lithostratigraphic units.

The interest on the stratigraphy of the Brazilian sedimentary basins was increased with the beginnings of oil research, made initially by Conselho Nacional do Petróleo and later by PETROBRAS (the Brazilian government oil company). None the less the orientation followed by Petrobrás was to remake the stratigraphic classification based almost exclusively on lithostratigraphic units – the formations. Later extremely important advances were made based on the utilization of biostratigraphic and chronostratigraphic units – the biozones and the chronozones.

The right way for a solution to the problem of classifying the Brazilian Cretaceous lies on the utilization of the time factor, and a precise description of the stages, following a comparison to their type sections. The chronozones that cannot be compared must be defined and receive local, formal denominations.

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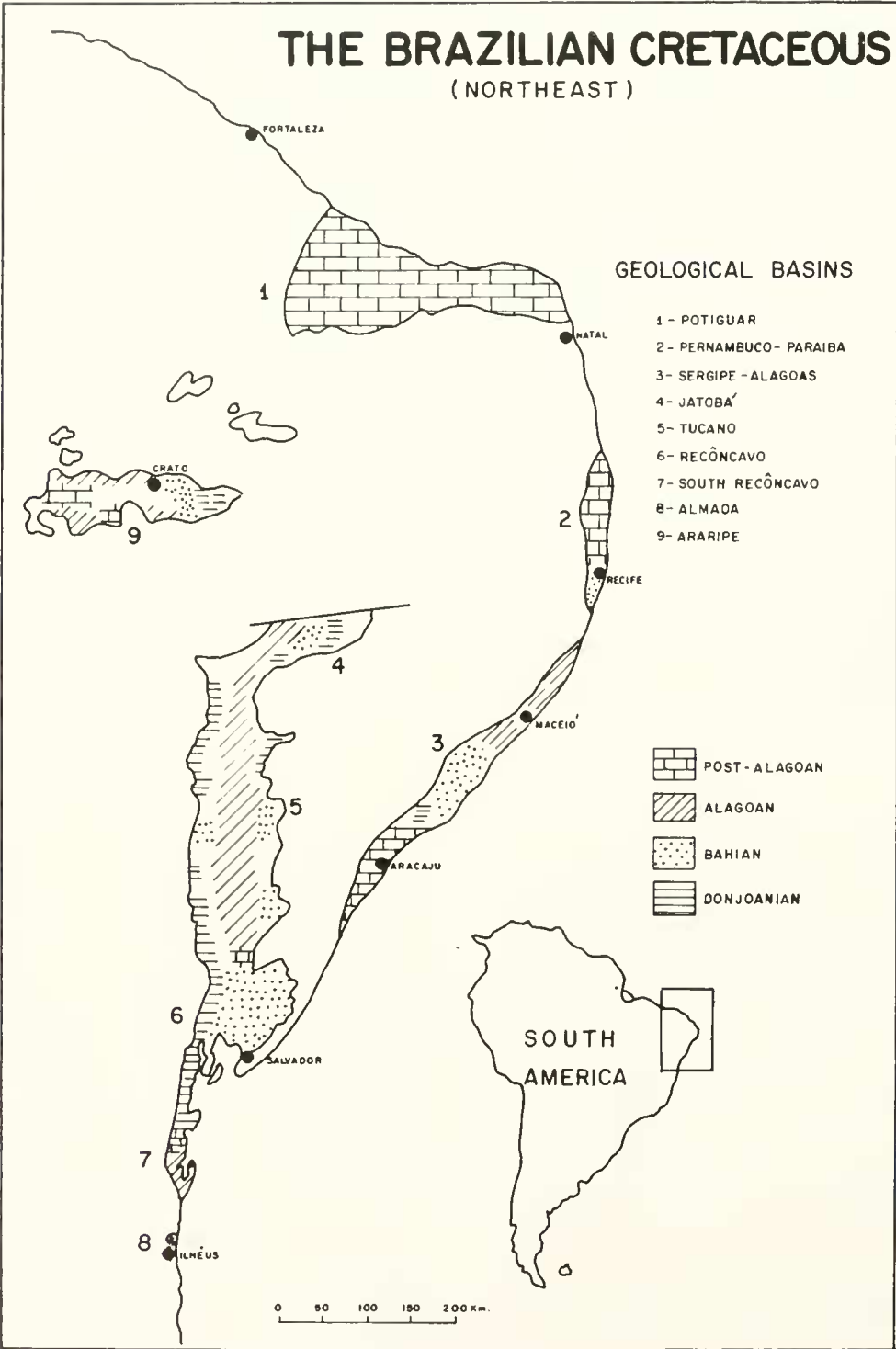
^{*)} I. M. BRITO, Instituto de Geociências UFRJ, C.C.M.N., 21910 Rio de Janeiro, Ilha do Fundão, Brazil; D. A. CAMPOS, Departamento Nacional de Produção Mineral, Seção Paleont., Av. Pasteur 404, 22290 Rio de Janeiro, Brazil.

THE BRAZILIAN CRETACEOUS

There is no doubt that the Cretaceous is one of the best known geological periods in Brazil, being well represented at the basins of the Northeast, in the continental shelf and even in areas of the great paleozoic basins.

The Cretaceous was first recognized in this country by GEORGE GARDNER, after his trip to Chapada do Araripe in 1838, and whose results were initially published with LOUIS AGASSIZ's in 1841. The latter author studied the fish collections made by the former who mentions "he immediately, from

their zoological characters alone pronounced them to belong to the Chalk Series" (GARDNER, 1849, p. 159). Before this palaeontological observation, GARDNER (op. cit., p. 155) makes comments on the layers showing nodules of fossil fishes, stating that "the circumstance that first led me to suspect this rock belonged to the Chalk Formation was an immense accumulation of flints and septaria similar to those of the Chalk of England, which I found on the activity of the range during a journey made along its base to the north of Crato".



HARTT (1870, p. 555) discusses the occurrence of Cretaceous formations in Brazil, stating that "the cretaceous rocks of Brazil are unknown on the coast south of the Abrolhos, which islands I believe to be outliers of this formation. Properly speaking the Cretaceous deposits begin a few miles south of the Bay of Bahia, and occur at intervals along the coast northward, occupying, at least in several instances, separate basins, some of which are fresh-water. We find Cretaceous rocks in Bahia, Sergipe, Alagoas, Pernambuco, Parahyba do Norte, Ceará, and Piahy".

In a little more than a hundred years of studies, a great deal of scientific work has been made on the Brazilian Cretaceous.

Although the occurrence of Cretaceous fossils in the Amazon Region has been quoted since last century, there are no records of sediments from that region, that could undoubtedly be attributed to the Cretaceous. With no fossil evidence whatsoever, the rocks from the Takutu Formation, Territory of Roraima, are attributed to the system, as well as those from Acre Group, in the northwest part of the State of Acre. In the Amazon Basin there are some layers currently designated Alter do Chão, which have been at least partly attributed to the Cretaceous and which bear stronger palaeontological evidence such as teeth, which have been assigned to theropod dinosaurs; however, the teeth could also be considered as belonging to sebecosuchian crocodilians, in which case they would not necessarily indicate the Cretaceous period, since those reptiles can also be found in the South American Tertiary.

In the State of Mato Grosso the Brazilian geological literature has traditionally shown the Parecis Formation as being Cretaceous, based on a poor study of its fossil woods, which has never been reviewed. The woods were collected in Serre do Norte, in the first quarter of this century. They can have an age varying from Permian to Tertiary.

In the Paraná Basin there are two formations covering the basalt, and which have been attributed to the Cretaceous. The lowermost – Caiuá Formation – shows, as fossil evidence, tracks belonging to tetrapod, which can only be considered as Mesozoic. On the other hand, the superior layer – Bauru Formation (including the Uberaba facies) – shows a varied reptilian fauna, including saurischian dinosaurs, mesosuchian and sebecosuchian crocodilians, pleurodire turtles and iguanid lizards, as well as anuran amphibians, fish, bivalves and carophyte algae. This fauna suggests the Cretaceous, although its endemic character cannot indicate precisely any stage; nevertheless it has traditionally been considered Senonian.

In the coastal and interior basins of the Brazilian Northeast the Cretaceous is shown in its most complete form, since the Jura-Cretaceous transition up to the topmost layers of the Maastrichtian. It is the only record of geological times indicating the opening of the South Atlantic Ocean, comprising sediments from the Potiguar, Pernambuco-Paraíba, Sergipe-Alagoas, Recôncavo-Tucano-Jatobá, Almada and Araripe basins, as well as those from the small northeastern basins. As part of the same cycle of geological events are the basins from the continental margin (which will not be discussed here) and the Cretaceous continental deposits from Parnaíba and São Francisco basins.

The succession of events that took place since the Jura-Cretaceous transition until the Lower Tertiary can be divided in four phases, recognizable from their deposition environments: continental, lacustrine, saline and marine. Palaeontological evidence confirms this subdivision.

The first three phases will be discussed here as the "Brazilian Lower Cretaceous", and the last, starting at the top of the Aptian, will be briefly considered as the "Marine Cretaceous".

Itapecuru (Parnaíba basin), Urucuia (São Francisco basin) and Exu (Araripe basin) formations represent sediments from continental environments and show some difficulty of correlation; only their lower age has been determined.

THE LOWER CRETACEOUS IN BRAZIL

The geocratic conditions initiated at the end of the Palaeozoic Era and accentuated during the Triassic, were modified by the end of the Jurassic and at the beginning of the Cretaceous, culminating with the separation of the South American and African plates and allowing a penetration of the sea, since the Aptian.

Before that event took place, however, the Northeast of Brazil underwent various phases which are also in its corresponding equivalent basins from Western Africa.

The continental, lacustrine and transition phases, with abundant non-marine ostracods, have tentatively been correlated to the Wealden or Neocomian, but truly they do not show condition for comparison with the international stages of the Cretaceous described in France or Switzerland, which are based on a marine fauna. Moreover they have a thickness of approximately 6,000 metres, which is well above the total Cretaceous stages below the Albian in their type localities, and which could represent a much greater deposition time span.

The continental phase (pre-rift) is represented by the sediments from the Bananeiras and Serraria formations (Sergipe-Alagoas Basin), Aliança and Sergi formations (Recôncavo-Tucano-Jatobá Basin) and by the Brejo Santo Formation (Araripe Basin). These formations have been attributed to the Purbeckian Stage, owing exclusively to their Continental characteristics. The lack of marine fossils does not allow an exact correlation with the standard stratigraphic column, and therefore the geologists of Petrobrás, have designated Brotas or Dom João stage the time interval when those sediments were deposited. We here propose that, formally, this time interval be denominated Donjoanian Stage, with its type area being represented by the sediments from the Aliança and Sergi formations, in the area of the Dom João oil field, at the Recôncavo.

The lacustrine phase (rift) is represented by the sediments from the Pastos Bons Formation (Barreirinha and Parnaíba basins), Corda Formation (Parnaíba Basin), Cabo Formation (Pernambuco-Paraíba Basin), Coruripe Subgroup (Sergipe-Alagoas Basin), Bahia Group (Recôncavo-Tucano-Jatobá and Almada basins), Missão Velha Formation (Araripe Basin) and Areado Formation (São Francisco Basin). These formations have been attributed to the Neocomian or Wealden, owing to their continental characteristics. The existing fossils

do not allow an exact correlation with the marine stages of the Lower Cretaceous from the standard stratigraphic column. Some geologists have utilized a Recôncavo Series with the Dom João (already discussed above), Rio da Serra, Aratu, Buracica, Jiquiá and Alagoas stages. The Rio da Serra, Aratu, Buracica and Jiquiá stages represent the time interval in which the mentioned sediments were deposited during that phase. We here propose that this time interval be formally designated Bahian Stage, with its type area represented by all layers that were deposited between the top of the Sergi Formation and the base of the Marizal Formation, at the Recôncavo-Tucano Basin.

The saline phase is represented by the sediments from the Codó and Grajaú formations (Parnaíba Basin), Muribeca Formation (Sergipe-Alagoas Basin), Marizal and Taipu-Mirim formations (Recôncavo-Tucano-Jatobá Basin) and the Santana Formation, except its upper part (Araripe Basin). These formations have been attributed to the Aptian, but the existing fossils do not allow a perfect correlation to the marine sediments from the Aptian type area. Various authors have, therefore, utilized the local denomination Alagoas stage to designate the time interval that those units were deposited. We here propose the formal designation Alagoan Stage for that time interval, with its type area corresponding to the occurrence of the Muribeca Formation, in the Sergipe-Alagoas Basin.

THE DONJOANIAN STAGE

The oldest fossiliferous layers from the mesozoic continental sequence in the Brazilian continental basins and the Western African coast are constituted mainly of shales and red siltstones overlaid by sandstone which are practically barren, represented in Brazil by the Aliança and Sergi formations, in the Recôncavo-Tucano-Jatobá Basin, and their equivalents: Bananeiras and Serraria formations in the Sergipe-Alagoas Basin, Brejo Santo Formation in the Araripe Basin, and also the Agoula, M'Vonne and N'Dombo formations in the Gabon Basin.

These formations are separated from the oldest and the newest by unconformities which are said to be palaeontologically characterized: in their lowest part, by lacustrine ostracods of very reduced size, belonging to the *Bisulcocypris pricei* biozone, also represented by other fossils such as *B. uninodosa* and some forms of *Metacypris*, *Candona* and *Darwinula*. In the uppermost part of the sequence, which is sandy and almost barren, are found locally silicified tree stems attributed to *Dadoxylon benderi*.

SCHALLER (1969, p. 76) suggested the designation "Brotas stage" to the sequence. This name has been better known in the lithostratigraphic nomenclature of Bahia than the chronostratigraphic nomenclature. The author also discusses that the Brotas stage corresponds to a badly defined part of the Upper Jurassic which owing to the lack of marine fossils, cannot establish an exact correlation to the international chronostratigraphic column.

Still according to SCHALLER (op. cit.) the sediments from the Brotas stage are recognized in the Recôncavo-Tucano-Jatobá Basin (Aliança and Sergi formations), Sergipe-Alagoas Basin

(Bananeiras, Serraria and Candeeiro formations), Araripe Basin (Missão Velha Formation) and in Africa by the sediments pre-Cocobeach in the Gabon Basin.

VIANA et alii (1971) replace the name Brotas stage by the designation Dom João, a name taken from an oil field located in the northwest of Todos os Santos Bay, approximately 4 km northeast of São Francisco do Conde in the State of Bahia.

In a short description made by VIANA (1980, p. 833), this author states that "the sediments belonging to this stage comprise the oldest fossiliferous layers of the continental sequence, and are considered to be of Upper Jurassic age. They are represented by an association of lacustrine ostracods where *Bisulcocypris* and '*Metacypris*' are predominant; the two species show abnormally reduced dimensions. Side by side with *B. pricei*, the major fossil guide, is found *Darwinula* cf. *D. oblonga* (ROEMER), of normal dimensions and reasonably frequent; Conchostraca, fish remains are also found and, in the uppermost part of the stage, where microfossils are almost non-existent, are found silicified tree stems of *Dadoxylon benderi* in certain areas, within a thick sandstone layer".

As to the fossil guides, which are said to be important in the Donjoanian Stage, we have the following comments:

PINTO and SANGUINETTI (1958) have described *Bisulcocypris pricei* and *B. uninodosa* from terrains which are said to belong to the Upper Jurassic of Pernambuco from a locality called Taboleiro Redondo, which is approximately 7 km from Icó, municipality of Petrolândia, and therefore from an area very far away from the stage's type locality, its precise chronologic equivalent must be discussed and investigated.

As to the fossil tree stems found in the superior part of the sequence, and attributed to *Dadoxylon benderi*, we remind that MUSSA (1959) described the species based on a stem fragment which is said to have been collected in the neighbourhood of Malhada dos Bois, on the road to Propriá, in the State of Sergipe; those terrains were attributed to the Japoatã Formation at that time.

That fossils locality seems to us rather doubtful. Other studies on the anatomy of the fossil woods from that region and other mapped localities such as Sergi Formation and its chrono- or lithostratigraphic equivalents, have not yet been undertaken.

The palaeontological content from the Donjoanian Stage still needs a better definition, as well as the acrozones of its possible fossils. The same is true of the position of the unit within the Upper Jurassic or Cretaceous.

THE BAHIAN STAGE

The Bahian Stage was proposed by HARTT (1870, p. 556) as Bahian Group: "for the fresh-water beds at Bahia, I would propose the name Bahian group". We would remind the reader that the term group had a chronostratigraphic connotation at that time.

As to the age, environment and palaeontology of the area considered as type in the present paper, HARTT (1870, p. 555) states that "the fossil mollusks of the fresh-water beds of the Bahia Basin have a very strong wealden look, but they are associated with teleostian fishes and other remains, which are

certainly cretaceous. They evidently belong low down in the series, and they may represent the Néocomien”.

SCHALLER (1969, p. 76) presented a subdivision of the terrains overlaying the “Brotas stage” into Santo Amaro, Ilhas, São Sebastião e Jiquiá stages. The first would be constituted by the *Cypridea ambigua* and *Cypridea (Morinina) candeiensis* biozones; the second by the *Cypridea (Morinina) bi-bullata*, *Paracypridea obovata* and *P. brasiliensis* biozones; the São Sebastião stage is characterized by the *Cypridea (Sebastianites) fida-Petrobrasias marfinensis* biozone; the Jiquiá stage by the *Candona ?centroimpressa* and *Cyprideis ?rugosa* biozone. These chronogeological units are overlaid by the Alagoas stage.

VIANA et alii (1971) replaced the denominations Santo Amaro, Ilhas, São Sebastião by Rio da Serra, Aratu and Buracica.

VIANA (1980, p. 834) summarizes the four stages of the “rift” stage with its palaeontological zones.

The non-marine terrains located above those of the Donjoanian Stage and below the Alagoan Stage will be included in the Bahian Stage; they are both separated by clear-cut unconformities. They belong to the Bahia Group, in the sense given by BRITO (1979, p. 67), together with their equivalents already described in the lacustrine phase, as well as the formations belonging to the Cocobeach Group from Gabon and their equivalents.

Its most typical fossils are ostracods, pollen, and also mollusks, fish and reptiles. The ostracods and pollen are distributed in various zones which have already been grouped in “stages”, according to SCHALLER (1969), VIANA et alii (1971) and VIANA (1980).

THE ALAGOAN STAGE

SCHALLER (1969, p. 77) observed that the name Alagoas, proposed by Branner to designate the section of betuminous shales that occur along the coast of the state of Alagoas, was being utilized to designate perforated sediments in the south of Bahia and north of Espírito Santo states. He proposed therefore that the name should be abandoned from the lithostratigraphic nomenclature and formally included in the stratigraphic column as the Alagoas stage.

SCHALLER (op. cit., p. 79) still mentions that the Alagoas stage includes sediments from the base of the Riachuelo Formation, from which he called Muribeca and Ponta Verde, also including strata from the superior part of the Coqueiro Seco Formation.

The chronostratigraphic unit in question would be underlying the Aptian and overlaying what has been designated the Jiquiá Stage, which would include the upper Aptian in its upper part, with a marine facies containing a scanty ammonoid fauna, foraminifera and nannofossils.

VIANA (1980, p. 835) states that the Alagoas stage is stratigraphically equivalent to the Aptian, being a thick sedimentary packet which consists mostly of non-marine deposits: in its upper one third, the continental fauna gradually disappears. At the top of the section appear foraminifera, nannofossils and the ammonite *Chelonicerias*.

The same author still mentions that the microfossils which are found in the Alagoas stage allow a reasonable biostratigraphic correlation to those from the Western Africa basins, however, up to the present time the identified types have not enough stratigraphic control to allow an exact Aptian age.

The Alagoan Stage here proposed, the denomination of which derives from the State of Alagoas in the Brazilian Northeast, includes the formations laying above the Bahian Stage and below the frankly marine formations from the Upper already mentioned in the saline phase.

It is possibly located on the upper to middle part of the Lower Cretaceous, its best known fossils being fishes such as *Vinctifer*, which is found in the Santana, Codó and Marizal formations, and non-marine ostracods.

THE MARINE CRETACEOUS

The marine phase is represented by sediments which span from the Aptian-Albian to the Lower Tertiary, in the Alcântara Formation (São Luís Basin), Açú and Jandaíra formations (Potiguar Basin), Paraíba Group (Pernambuco-Paraíba Basin), Sergipe Group (Sergipe-Alagoas Basin), Algodões Formation (South Recôncavo Basin), Urucutuca Formation (Almada Basin) and the upper part of the Santana Formation (Araípe Basin). These sediments are marine, and their correlation with the stages of the standard stratigraphic column is relatively well-established on the basis of ammonites, foraminifera and other important fossil groups.

The fossils from the Brazilian marine Cretaceous have been studied since last century, and their stratigraphic positions have been reasonably ascertained within the international geological column.

Among the pioneer studies that of HYATT in HARTT (1870, p. 385) deserves to be mentioned. He classified as Cretaceous the fossils, mostly ammonites, from the Maruim Region, Sergipe; HARTT (1870, p. 555) made comments on the layers overlaying the Maruim limestones, stating that “over these are the flaggy white and grayish limestones with *Inoceramus*, ammonites, fish, etc., apparently representing the White Chalk, Sénonien”.

WHITE (1887) gives a Cretaceous age to the mixed collections from Pirabas, Maria Farinha and Sergipe.

The Brazilian terrains from the marine Cretaceous started to be better distributed in the various classical and international stages with the work of MAURY (1924, 1930, 1936).

A great number of studies on the geology and palaeontology from the Brazilian Cretaceous have been published in the last decades (see BRITO, 1979). However, after detailed research was carried out mainly by specialists from Petrobrás and by REYMENT and BENGTSON, from University of Uppsala, all the stages of the system that are located above the Upper Aptian were then well defined on the coastal basins of Brazil, mainly in the Northeast, through ammonite zones, foraminifera and other microfossils.

According to BENGTSON (1979, p. 542), “the extremely rapid evolution of ammonoids and inoceramids during the Cretaceous in combination with their wide geographical distribution make these fossils the best suited to be used on a

precise stratigraphic zoning. The microfossils do not offer the same possibilities, but they are essential to a subsurface correlation”.

On the basis of ammonites mainly, the marine Cretaceous from Brazil is already relatively well subdivided in the following biozones:

Maastrichtian	<i>Sphenodiscus</i> – <i>Pachydiscus</i> biozone
Campanian	Foraminifera biozones
Santonian	Foraminifera biozones
Coniacian	<i>Prionocycloceras</i> – <i>Barroisiceras</i> biozone

Upper Turonian	<i>Subprionocyclus</i> biozone
Middle Turonian	<i>Benueites</i> – <i>Coilopoceras</i> – <i>Mammites</i> biozone
Lower Turonian	<i>Pseudaspidoceras</i> – <i>Vascoceras</i> – <i>Inoceramus labiatus</i> biozone
Cenomanian	<i>Kanabicerias</i> ; <i>Acanthoceras</i> ; <i>Stoliczkaia</i> – <i>Graysonites</i> biozones
Upper Albian	<i>Mortoniceras</i> – <i>Elobiceras</i> biozone
Middle Albian	<i>Oxytropidoceras</i> biozone
Lower Albian	<i>Douvilleiceras</i> biozone
Upper Aptian	<i>Chelonicerias</i> biozone

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Plate 1

- Fig. 1: DONJOANIAN STAGE – Reddish siltstones of Bananeiras (Aliança) Formation overlain by sandstones of Serraria (Sergi) Formation in a highway cut between Aracaju and Propriá, State of Sergipe.
- Fig. 2: BAHIAN STAGE – Montesserrate Conglomerate near Salvador fault, State of Bahia.
- Fig. 3: BAHIAN STAGE – Contact between Agua Comprida Conglomerate and lacustrine shale in a highway cut between Salvador and Feira de Santana in Simões Filho, State of Bahia.
- Fig. 4: ALAGOAN STAGE – Rhythmites, turbidites and sandstones of Muribeca Formation at Morro de Camaragibe, State of Alagoas.

